

CLAIMS

1. A multi-tone modem with a plurality of components forming a transmit path and a receive path; and the receive path components of the multi-tone modem
5 comprising:
 - a fast Fourier transform (FFT) component to convert multiple received tones in a time domain to successive symbols in a frequency domain, with each of the successive symbols including pilot sub-symbols together with message sub-symbols;
 - a message processor coupled to the FFT and the message processor operable
10 to select pairs of message and pilot sub-symbols in each symbol and to equalize the message sub-symbol with the pilot sub-symbol in each pair of sub-symbols to substantially remove from the message sub-symbol frequency dependent phase shifts between the tones of each symbol; and
 - a decoder coupled to the message processor for decoding each message sub-
15 symbol equalized in the act of equalizing to the corresponding message data.
2. The multi-tone modem of Claim 1, wherein the message sub-symbol and the pilot sub-symbol correspond with a message tone and a pilot tone adjacent to one another in the frequency domain.
20
3. The multi-tone modem of Claim 1, wherein the message processor further comprises:
 - a pseudo-equalizer for multiplying the message sub-symbol times the complex conjugate of the pilot sub-symbol in each pair of message and pilot sub-symbols to
25 substantially remove from the message sub-symbol the frequency dependent phase shifts therein.
4. The multi-tone modem of Claim 1, further comprising:
 - a frequency domain equalizer (FEQ) coupled to the FFT in parallel with the
30 message processor and the FEQ operable during the training phase of operation to

determine a coefficient vector with an inverse frequency response of a communication channel using the pilot sub-symbols from the FFT.

- 5 5. The multi-tone modem of Claim 1, wherein the message processor further comprises:
 a de-scrambler to de-scramble the message sub-symbols and the pilot sub-symbols to remove effects of any scrambling thereof during transmission.
- 10 6. The multi-tone modem of Claim 1, wherein the message processor further comprises:
 a de-scrambler for asymmetrically de-scrambling the message sub-symbols and the pilot sub-symbols with the asymmetrical de-scrambling resulting in each message sub-symbol and pilot sub-symbol exhibiting a fixed phase bias; and
 wherein the decoder further decodes each message symbol with a decoding
15 table which removes the fixed phase bias imparted by the de-scrambler.
- 20 7. The multi-tone modem of Claim 1, wherein the message processor further comprises:
 a diversity combiner for combining selected ones of the equalized message sub-symbols redundant with respect to one another in terms of the message data encoded therein to produce at least one unique message sub-symbol with a reduced noise level therein; and
 wherein the decoder further decodes the at least one unique message sub-symbol to
25 the corresponding message data.
- 30 8. A method for demodulating data received over a communication medium with a communication channel with multiple pilot tones with pilot data modulated thereon and message tones with message data modulated thereon; and the method for demodulating comprising:
 converting the received data from a time domain to a frequency domain with the received data in the frequency domain including successive symbols each including pilot sub-symbols together with message sub-symbols;

selecting pairs of message and pilot sub-symbols in each symbol;
equalizing the message sub-symbol with the pilot sub-symbol in each pair of
sub-symbols to substantially remove from the message sub-symbol frequency
dependent phase shifts imparted to the communication channel; and
5 decoding each message sub-symbol equalized in the act of equalizing to the
corresponding message data.

9. The method for demodulating of Claim 8, wherein the message sub-symbol and
the pilot sub-symbol correspond with a message tone and a pilot tone adjacent to one
10 another in the frequency domain.

10. The method of Claim 8, wherein the equalizing act further comprises the act of:
multiplying the message sub-symbol times the complex conjugate of the pilot
sub-symbol in each pair selected in the act of selecting to substantially remove from the
15 message sub-symbol the frequency dependent phase shifts therein.

11. The method of Claim 8, further comprising the act of:
determining in parallel with the equalizing act, a coefficient vector with an
inverse frequency response of a communication channel using the pilot sub-symbols
20 converted in the converting act.

12. The method of Claim 8, wherein the act prior to the selecting act of:
de-scrambling the message sub-symbols and the pilot sub-symbols to remove
effects of any scrambling thereof during transmission.
25

13. The method of Claim 8, wherein the act prior to the selecting act further
comprises:
asymmetrically de-scrambling the message sub-symbols and the pilot sub-symbols
with the asymmetrical de-scrambling resulting in each message sub-symbol and pilot
30 sub-symbol exhibiting a fixed phase bias; and

wherein further the decoding act further comprises decoding each message symbol with a decoding table which removes the fixed phase bias imparted in the asymmetrical de-scrambling act.

5 14. The method of Claim 8, further comprising the act prior to decoding act of:
combining selected ones of the message sub-symbols equalized in the act of
equalizing, with the selected ones of the message sub-symbols redundant with respect
to one another in terms of the message data encoded therein to produce at least one
unique message sub-symbol with a reduced noise level therein; and
10 with the decoding act decoding the at least one unique message sub-symbol to
the corresponding message data.

15 15. The method of Claim 8, wherein the communication channel established over
the communication medium exhibits a Digital Subscriber Line (DSL) protocol
implemented with a discrete multi tone (DMT) modulation.

16. The method of Claim 8, wherein the communication medium comprises one of
a wired medium and a wireless medium.

20 17. A method of modem training between at least two modems comprising the
steps performed at a receiving one of the at least two modems of:
converting a training set of pilot tones and message tones from a time domain
to a frequency domain with the received data in the frequency domain including
successive training symbols each including pilot sub-symbols together with message
25 sub-symbols;
selecting pairs of message and pilot sub-symbols in each training symbol;
equalizing the message sub-symbol with the pilot sub-symbol in each pair of
sub-symbols to substantially remove from the message sub-symbol frequency
dependent phase shifts between the tones of each training set; and
30 decoding each message sub-symbol equalized in the act of equalizing to the
corresponding message data.

18. The method of modem training of Claim 17, wherein the message sub-symbol and the pilot sub-symbol correspond with a message tone and a pilot tone adjacent to one another in the frequency domain.

5 19. The method of modem training of Claim 17, wherein the equalizing act further comprises the act of:

multiplying the message sub-symbol times the complex conjugate of the pilot sub-symbol in each pair selected in the act of selecting to substantially remove from the message sub-symbol the frequency dependent phase shifts therein.

10

20. The method of modem training of Claim 17, further comprising the act of:
determining a coefficient vector with an inverse frequency response of a communication channel using the pilot sub-symbols converted in the converting act.

15 21. The method of modem training of Claim 17, wherein the act prior to the selecting act of:

de-scrambling the message sub-symbols and the pilot sub-symbols to remove effects of any scrambling thereof during transmission.

20 22. The method of modem training of Claim 17, wherein the act prior to the selecting act further comprises:

asymmetrically de-scrambling the message sub-symbols and the pilot sub-symbols with the asymmetrical de-scrambling resulting in each message sub-symbol and pilot sub-symbol exhibiting a fixed phase bias; and

25 wherein further the decoding act further comprises decoding each message symbol with a decoding table which removes the fixed phase bias imparted in the asymmetrical de-scrambling act.

30 23. The method of modem training of Claim 17, further comprising the act prior to decoding act of:

combining selected ones of the message sub-symbols equalized in the act of equalizing, with the selected ones of the message sub-symbols redundant with respect

to one another in terms of the message data encoded therein to produce at least one unique message sub-symbol with a reduced noise level therein; and

with the decoding act decoding the at least one unique message sub-symbol to the corresponding message data.

5

20200201 09:56:00